Integrating energy performance software into Arc 334L; Environmental Controls II

Meadows Foundation
Curriculum Development Grants

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Integrating energy performance software into Environmental Controls II

The intent of (Arc 334L) Environmental Controls II is to learn to integrate environmental control systems into the form making process of architectural design. This course is intended to be one of a series of building science courses, which describe the function of building in filtering the environment about their occupants. Environmental Controls I considered the fundamentals of Lighting, Electrical Systems and Acoustics. Environmental Controls II considers the application of the thermal environment, the issues of water systems and the application of the fire code as well as other technical problems encountered in building design. Environmental Controls II focuses on how the various human sensory systems are supported by related mechanical, building and environmental controls sub-systems. The goal of the course is to develop a means by which designers can create energy-efficient buildings. The means include both: (1) to understand the forms and components of a building that provide efficiency and comfort; (2) processes for use in design that will encourage the selection of the proper physical responses and facilitate the investigation of the likely performance of these decisions. To analytically and physically evaluate the performance of the environmental control decisions students make in their design project, they learn in this course how to analyze the energy performance of a building's environmental control systems.

The purpose of this grant proposal is to facilitate the integration of new energy performance software into the Environmental Controls II that would replace tedious calculations that are currently done by hand.

How to Analyze the Energy Performance of a Building's Environmental Control Systems

The performance of a building's energy system can be measured or expressed in two ways, the functional performance and the energy performance.

The functional performance essentially expresses the success in achieving the operating parameters of the system such as thermal comfort, air quality, acoustical comfort, lighting comfort, lighting adequacy, etc.

The Energy performance is the amount of energy consumed to support each of the energy systems in the achievement of its functional performance.

In (Arc 334L) Environmental Controls II, the aspects of the functional performance and how they relate, respectively, to the energy performance are reviewed together. The essential thesis is that if one attempts to reduce energy consumption by reducing functional performance the effort will fail. This leads to the essential proposition that, in order to succeed, any energy reduction program in an existing building *must* improve the functional performance if it is to succeed. In order to accomplish this goal students should be able to readily see the energy performance of their building design and to review the implications of incremental design modifications on the energy performance of the building. This task requires students to assess the energy performance of their building design at different stages of the design process.

Currently the calculations for a verified energy audit are done by hand or through rules-of-thumb using guidelines described by American Society of Heating and Air Conditioning Engineers (ASHRAE) and the Air Conditioning Contractors of America (ACCA).

gbXML

ASHRAE and ACCA are the nationwide associations of heating, ventilation, air conditioning, and refrigeration (HVACR) contracting professionals and businesses, and they established the Manual J residential load calculation system which, is now referenced to as the Green Building XML (gbXML) schema. gbXML provides a means for true interoperability between popular computer aided drafting (CAD) software and HVACR-specific design software.

The Green Building Studio of California developed the gbXML schema. The latest file format allows drafting software to pass onto calculation software details of a building's dimensions and the materials used in construction.

Manual J procedures use over 500 material codes to describe common roof, wall, and glass building materials. The gbXML schema makes it easier for HVACR designers to perform Manual J calculations from a CAD drawing.

XML, extensible markup language, is a type of computer language that allows software programs to communicate information with little to no human interaction.

This approach allows building designers to focus on what they want to do most - design beautiful, environmentally responsible buildings that use intelligent technologies to meet their needs. Helping realize the promise of Building Information Modeling, gbXML allows intelligent solutions for the design, certification, operation, maintenance, and recycling of buildings. The possibilities are limited only by the collective imagination of the building design.

Manual J

Manual J is the ANSI-approved national standard for determining residential heating and cooling load calculations. "Manual J" is a registered trademark of the Air Conditioning Contractors of America. When sizing a heating and cooling system for a small building, rules-of-thumb measurements can yield an improperly sized system. The popular method of calculating heating and cooling loads is to use ACCA, Manual J-compliant load calculation software. The old method of buying a Manual J book and sizing by hand is rarely used these days due to all the great software available. ACCA's software and Technical Manuals are the bedrock of air conditioning in America. ACCA procedures are required by the City of Austin and many other building codes and municipal laws.

A version of the ACCA software that would be useful for Environmental Controls II students is Rhvac. Rhvac is the software program that allows the user to perform sizing parameters for environmental controls design procedures including; Manual J (load calculations), Manual S (equipment selection), Manual D (duct system design), Manual T (air distribution devices), and Manual H (heat pumps). Taken together, all comprise the recommended ACCA System Design Process.

Rhvac

* Calculates peak heating and cooling loads in accordance with Manual J.
* Calculates Duct Sizes, System Losses, and fan static pressure requirement in accordance with Manual D. Lets you enter the entire duct system, or only the path(s) with the highest pressure loss if you prefer.
* Determines building tonnage and room CFM requirements.
* Incorporates Manual J Addenda A, B, C, and D.
* Links to REM/Rate, Architectural Energy Corporation's popular home energy rating tool.
* Links to REScheck, DOE's energy codes program.
* Links to the Energy Gauge USA home energy-rating program.
* Generates a Building Rotation report that shows you tonnages and room CFM requirements at each rotation.
* Includes a Building Rotation Duct Size Preview window that shows you the heating and cooling CFM for each room or duct in the project for each rotation of the building, as well as the maximum duct size of all rotations.
* Calculates hydronic radiant floor tubing length required.
* Follows ACCA Manual J, 8th Edition. Rhvac is approved by ACCA.
* Computes room by room, zone, system & building.
    * Rooms and zones can be assigned to 15 systems.
* Allows 1000 rooms grouped into 10 zones per system using drag and drop zoning techniques.
* Allows 20 walls, 20 windows, 8 roofs, 6 floors and 6 doors per room.
* New! Includes a wide selection of spray foam and SIP roofs and walls.
* Allows custom construction materials and descriptions.
* Lets you specify lists of "Favorite" materials so you can select them easier.
* Remembers your most recent material selections so you can reselect them easily.
* Looks up HTM & U-values or lets you specify them.

* Determines Adequate Exposure Diversity status.
* Links to Ductsize, Energy Audit and PsyChart. The PsyChart program can import Rhvac system data directly into its Air Handler Model window.
* Displays psychrometric chart.
* Lets you select equipment from ARI and GAMA databases.
* Prints exploded color pie charts, bar graphs, and custom proposals.
* Allows decimal feet, feet-inches or metric length and width dimensions.
* Allows exterior shading (overhangs and offsets).
* Provides inputs for summer & winter partition temperature differences.

Rhvac quickly and accurately calculates peak heating and cooling loads for residential and small commercial buildings in accordance with the eighth edition of the ACCA Manual J. The Heat Transfer Multipliers (HTM values) for all the walls, windows, doors, and roofs listed in Manual J are stored and automatically looked up by the program as needed. Although HTM values are taken from Manual J directly, the user does have the option of entering his own U-Value for each wall, roof, or glass section so that a modified HTM value is used. Design weather data for over 1500 cities is built-in to the program. In addition, the user can revise the existing weather data and add additional weather data as desired. The program as needed automatically handles zoning cfm adjustments. Other outstanding features include exterior glass shading, ventilation air, miscellaneous latent loads, and default room data, automatic rotation of the entire building, hydronic heat calculations and much more.

Deliverables and Time Table

The project deliverable will include a report on a six-hour tutorial on how to integrate the use of three, energy performance modeling software with their sound building design projects. The how to report will include a step by step procedure on the ins and outs of how to utilize the software programs in analysis of student design projects and will include working examples. The timetable for this research is for the research and report to be completed over the summer term and be fully implemented into the course content of Arc 334L Environmental Controls when it is offered in the spring.

Budget

Faculty salary (1/2 summer + fringe)	$4,500.
Fringe	$1,350
Graduate research Assistant	
(50% time, 18 weeks, $15.50 hour)	$5,580
Fringe (15%)	$837
Graduate research Assistant)	
(50% time, 18 weeks, $15.50 hour)	$5,580
Fringe (15%)	$837
Computer software expenses related to the Research	$1,316
Total	$20,000

Research Process
2009-2010

During the summer and fall semester of 2009, Graduate Research Assistant Steven Matten and Professor Michael Garrison took a closer look at potential computer software that Environmental Controls II (Architecture 334) students could utilize in preparing the homework assignments that would integrate sustainability into the program. We started with an investigation of gbXML, Manual J and Rhvac. Of the three we settled on Manual J for an extensive investigation.

After a detailed analysis of gbXML, Manual J, and Rhvac all three were rejected as software that should be utilized by third year architecture and interiors students because the amount of class time required by the students to learn how to use the program gbXML was determined to be excessive at this time and that the programs for Manual J and Rhvac were primarily used for skin load dominated buildings like residential structures.

After additional analysis we determined that three other software programs that would be quick for the students to learn at this time would be more appropriate. These programs included Google SketchUp tied with Google Earth, eQuest thermal HVAC analysis and Rainwater Calculator. Google SketchUp will be tied to homework assignment, one and two which, concern solar shading and site analysis. eQuest will be tied to homework, three and four which concern thermal and HVAC design integration. And Rainwater Calculator software which will allow students to size cisterns for rainwater harvesting.

An analysis of each software is presented below:

gBXML

The Green Building XML schema, referred to as "gbXML", was developed to facilitate a common interoperability model integrating a myriad of design and development tools used in the building industry. gbXML is being integrated into a range of software CAD and engineering tools. This interoperability standard reduces the time to develop a building and also assures that when the building is put into operation it can meet the design intent.

gbXML: The Green Building XML schema, was developed to facilitate the transfer of building information stored in CAD building information models, enabling integrated interoperability between building design models and a wide variety of engineering analysis tools and energy performance modeling. gbXML has been adopted by the leading CAD vendors, Autodesk, and Graphisoft. With the development of export and import capabilities in energy modeling tools, gbXML has become a defacto industry standard schema. Its use dramatically streamlines the transfer of building information to and from energy performance models, eliminating the need for time-consuming plan take-offs. This removes a significant cost barrier to designing resource efficient buildings and specifying associated equipment. It enables building design teams to truly collaborate and realize the potential benefits of Building Information Modeling (BiM).

After careful review of this software program, we found that far too few of the third year architecture design students are proficient in BIM at this time and that teaching the students this software would ultimately take too much scheduled class time and take away too much class time from the analysis of environmental control systems. Although this software knowledge would ultimately benefit the architecture student we decided because of the long learning time that we should investigate other software programs that may be easily assimilated in the short class schedule time we are able to devote to learning new environmental analysis tools. However, when the use of Revit is more ubiquitous within the third year studios we may again return to this model because it allows interface between performance modeling, CAD and BIM.

Rhvac

Rhvac gives you more direct information on several ways on sizing ductwork. For those who do not want to enter complete details about a duct system, Rhvac can still suggest the number of registers needed for each room, the duct size leading to each register, and the initial size of the main trunk duct. For example, if a family room is calculated to require 200 CFM, Rhvac will suggest two registers to deliver 100 CFM each. And if flex duct was specified, Rhvac will "spin the ductulator" for you and calculate using the equal friction method that each duct should be 6" in diameter. And if the project needed 1200 CFM total, Rhvac knows that the first part of the main trunk has to carry that much air and it will calculate the main trunk size. **Automatically, for every project, Rhvac will tell you duct sizes and the initial main trunk size.** All you have to do is say what materials (steel, ductboard, or flex duct) are being used for trunk and ducts. You get lots of duct info with minimal input required. If you want to do a complete Manual D duct system analysis and include every duct section and fitting in the project, Rhvac also provides a free Manual D Duct Sizer. This is a tabular input procedure where you can either enter your entire duct system or just enough to calculate the fan static pressure requirement using a single route or "path." This unique tool includes a powerful Fitting Selector dialog that makes it easy to select from hundreds of fittings from ACCA's Manual D. And it also has Drawing Board and graphic Manual D Ductsize options to Rhvac.

The basic version of Rhvac provides complete Manual J load calculations and Manual D duct sizing using a simple manual entry tabular input process. The basic version of Rhvac provides no drawing capability, except at a demonstration level. To be able to draw floor plans and have duct sections automatically placed and sized on the drawing, you need to activate both Drawing Board and the graphic Manual D Ductsize modules in Rhvac. These modules are already inside of basic Rhvac, but operating at a demo level that limits the size of the building and number of duct sections that can be drawn.

A major feature of Rhvac is how well it works in either a manual entry or graphic entry mode. Those new to computerized load calculations often wonder whether they should start with basic Rhvac or go ahead and start with Rhvac and its graphic options such as Drawing Board and graphic Manual D Ductsize. It is easier to learn a manual entry system where you type your room dimensions in than a drawing system because a drawing system (regardless of vendor) involves all the additional concepts of computer aided drafting (CAD) such as layers, sheets, scales, and much more. Learning both Manual J and CAD concepts all at once is harder than just learning Manual J input procedures.

Rhvac is supplied with HVAC model performance data for most HVAC manufacturers. This data covers over 600,000 models of standard air conditioners, heat pumps, ground source heat pumps, furnaces, and boilers from over 250 HVAC manufacturers. HVAC data typically includes a model number, nominal capacity, SEER or other efficiency numbers, and the ARI reference number if applicable. Additionally, pictures of models for some of the more popular manufacturers such as Carrier, Trane, Goodman, Lennox, Armstrong, Rheem, York, Climate Master, Waterfurnace, Florida Heat Pump and others are included as well. Model data and pictures can be selected to appear in the reports for each system of an Rhvac project.

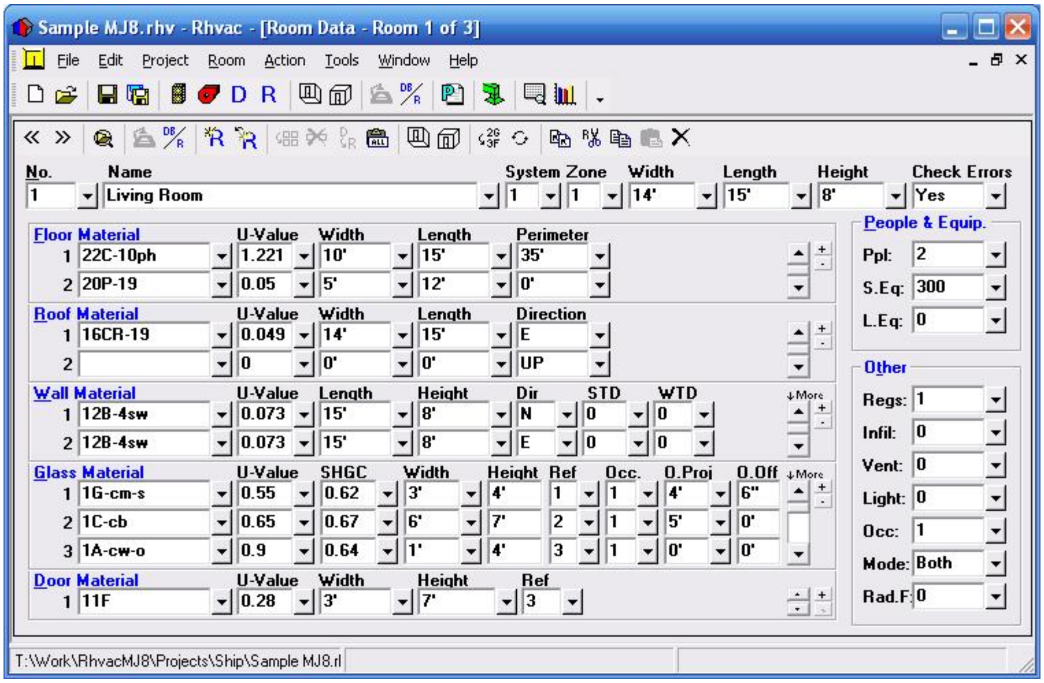
Calculation of Manual J HVAC loads for buildings using geothermal equipment is done no differently than for any other type of HVAC equipment. Rhvac calculates perfectly for all types of geothermal equipment. What is different about ground source heat pumps is that a "loop" design also needs to be performed. A loop is usually polyethylene tubing that is buried in the ground or submerged in a pond. This loop connects the heat pump to the ground or water. The length of tubing required in the loop is a special calculation. Elite Software offers a program called ECA (Earth Coupled Analysis) for the calculation of ground loops in horizontal, vertical, and "slinky" configurations. ECA can import all necessary data from Rhvac or be used stand-alone. See more details on ECA.Direct exchange heat pumps use copper tubing to connect the heat pump to the ground. Each manufacturer provides its own chart for sizing copper loops and thus loop-sizing software is not required. Both ground source and direct exchange heat pumps are more expensive than standard air source heat pumps.

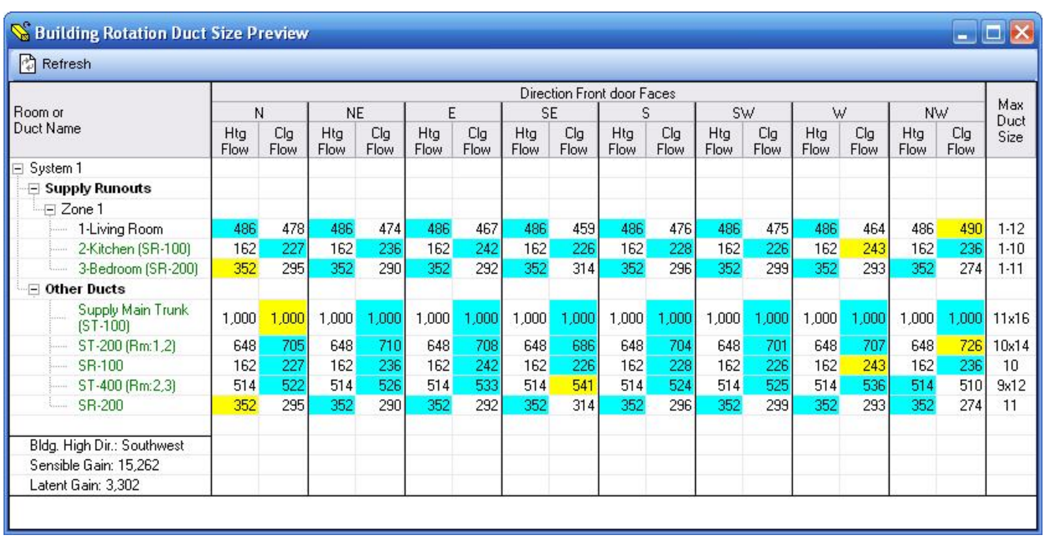
Building Rotation Duct Size Preview

This window shows you the room and duct airflows for each building rotation, as well as the maximum duct size of all rotations. It includes every duct in the project, whether from the automatic duct sizing of the main trunk and all other ducts, from ducts defined with the Manual D Ductsize component in Drawing Board, or from ducts entered with the Manual D Duct Sizer).

Room Data

The Room Data window is where you enter all the information about the room dimensions, as well as floor, roof, wall, glass, and door material information.





Building Rotation Duct Size Preview

Refresh

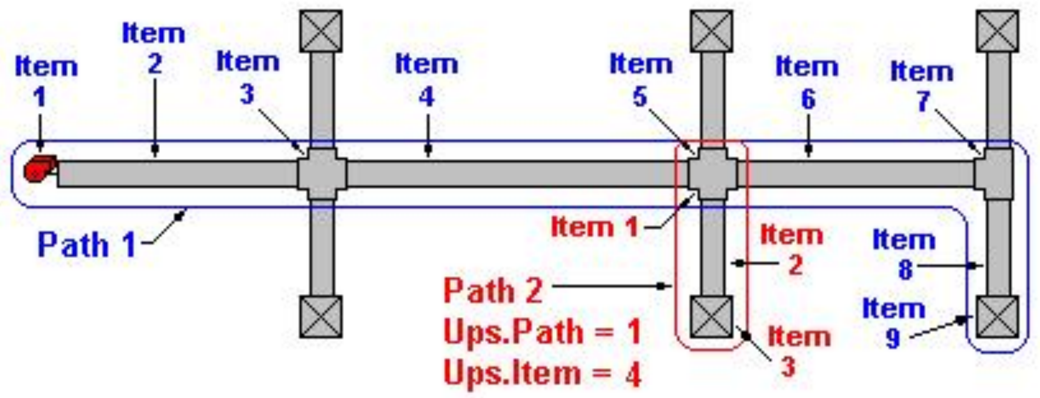
Room or Duct Name	N Htg Flow	N Clg Flow	NE Htg Flow	NE Clg Flow	E Htg Flow	E Clg Flow	SE Htg Flow	SE Clg Flow	S Htg Flow	S Clg Flow	SW Htg Flow	SW Clg Flow	W Htg Flow	W Clg Flow	NW Htg Flow	NW Clg Flow	Max Duct Size
System 1																	
Supply Runouts																	
Zone 1																	
1-Living Room	486	478	486	474	486	467	486	459	486	476	486	475	486	464	486	490	1-12
2-Kitchen (SR-100)	162	227	162	236	162	242	162	226	162	228	162	226	162	243	162	236	1-10
3-Bedroom (SR-200)	352	295	352	290	352	292	352	314	352	296	352	299	352	293	352	274	1-11
Other Ducts																	
Supply Main Trunk (ST-100)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	11x16
ST-200 (Rm:1,2)	648	705	648	710	648	708	648	686	648	704	648	701	648	707	648	726	10x14
SR-100	162	227	162	236	162	242	162	226	162	228	162	226	162	243	162	236	10
ST-400 (Rm:2,3)	514	522	514	526	514	533	514	541	514	524	514	525	514	536	514	510	9x12
SR-200	352	295	352	290	352	292	352	314	352	296	352	299	352	293	352	274	11

Direction Front door Faces

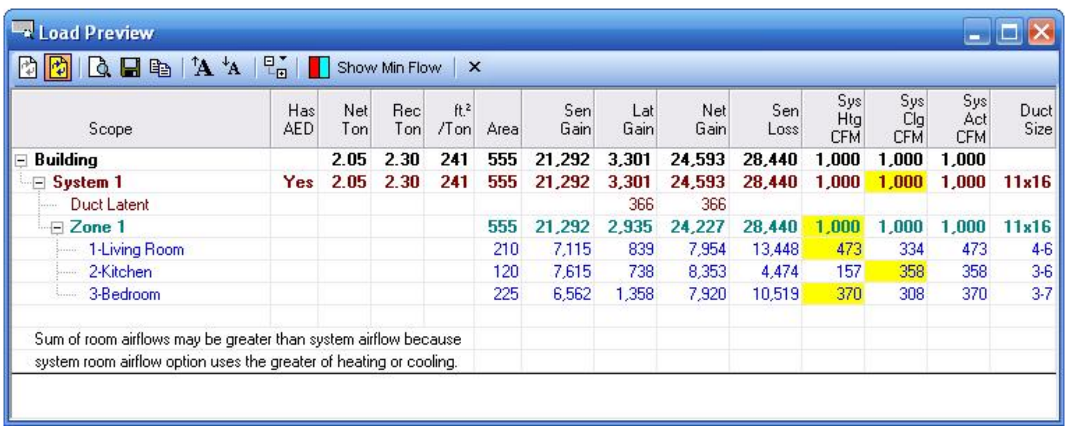
Bldg. High Dir.: Southwest
Sensible Gain: 15,262
Latent Gain: 3,302

Manual D Duct Sizer

The Manual D Duct Sizer window calculates duct sizes and the static pressure losses of your duct system. You can either enter your entire duct system, or just enough to calculate the fan static pressure requirement (one single route, or "path"). This unique tool includes a powerful Fitting Selector dialog, which makes it easy to select from hundreds of fittings from ACCA's Manual D.

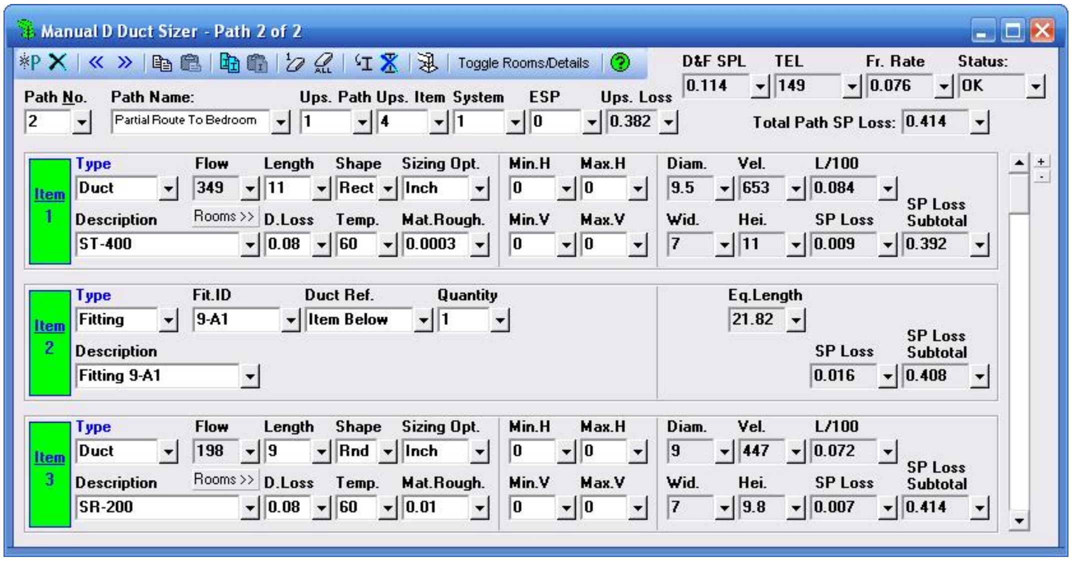


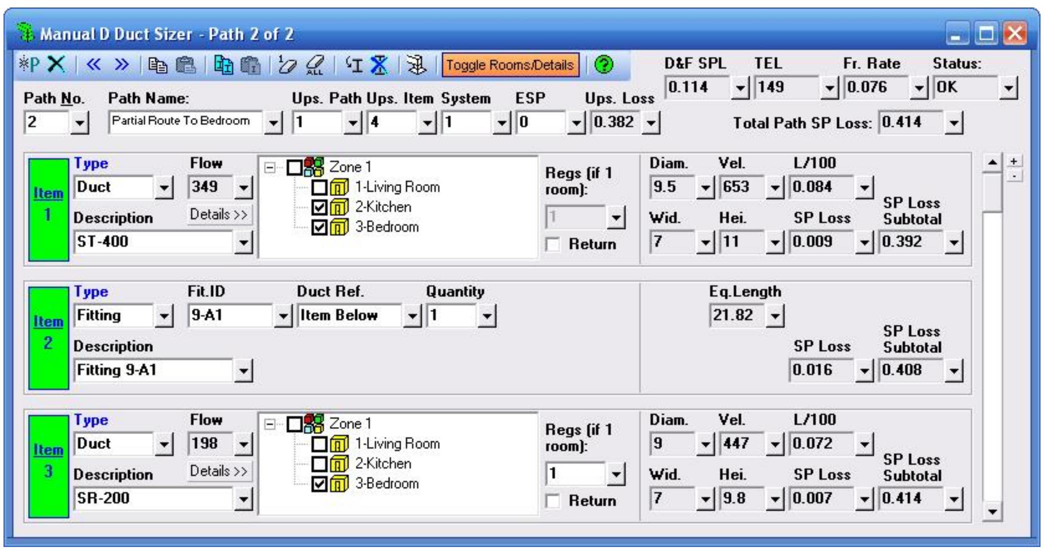
Load Preview
This window gives you an overall view of the project loads at each of the four calculation levels: Building, System, Zone and Room.

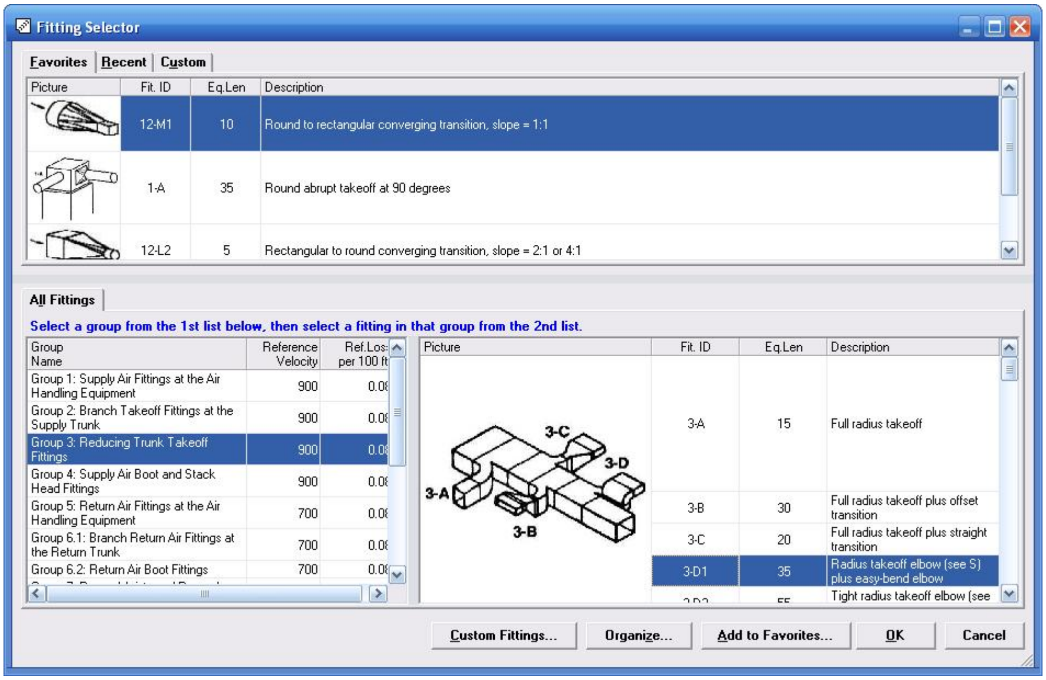


Scope	Has AED	Net Ton	Rec Ton	ft² /Ton	Area	Sen Gain	Lat Gain	Net Gain	Sen Loss	Sys Htg CFM	Sys Clg CFM	Sys Act CFM	Duct Size
Building		2.05	2.30	241	555	21,292	3,301	24,593	28,440	1,000	1,000	1,000	
System 1	Yes	2.05	2.30	241	555	21,292	3,301	24,593	28,440	1,000	1,000	1,000	11x16
Duct Latent							366	366					
Zone 1					555	21,292	2,935	24,227	28,440	1,000	1,000	1,000	11x16
1-Living Room					210	7,115	839	7,954	13,448	473	334	473	4-6
2-Kitchen					120	7,615	738	8,353	4,474	157	358	358	3-6
3-Bedroom					225	6,562	1,358	7,920	10,519	370	308	370	3-7

Sum of room airflows may be greater than system airflow because system room airflow option uses the greater of heating or cooling.

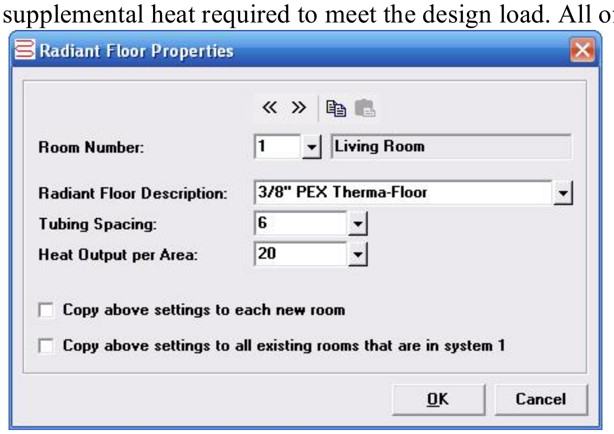

Manual D Duct Sizer - Path 2 of 2
Toggle Rooms/Details
D&F SPL 0.114
TEL 149
Fr. Rate 0.076
Status: OK
Path No. 2
Path Name: Partial Route To Bedroom
Ups. Path 1
Ups. Item 4
System 1
ESP 0
Ups. Loss 0.382
Total Path SP Loss: 0.414
Item 1
Type Duct
Flow 349
Length 11
Shape Rect
Sizing Opt. Inch
Min.H 0
Max.H 0
Diam. 9.5
Vel. 653
L/100 0.084
Description ST-400
Rooms >>
D.Loss 0.08
Temp. 60
Mat.Rough. 0.0003
Min.V 0
Max.V 0
Wid. 7
Hei. 11
SP Loss 0.009
SP Loss Subtotal 0.392
Item 2
Type Fitting
Fit.ID 9-A1
Duct Ref. Item Below
Quantity 1
Eq.Length 21.82
Description Fitting 9-A1
SP Loss 0.016
SP Loss Subtotal 0.408
Item 3
Type Duct
Flow 198
Length 9
Shape Rnd
Sizing Opt. Inch
Min.H 0
Max.H 0
Diam. 9
Vel. 447
L/100 0.072
Description SR-200
Rooms >>
D.Loss 0.08
Temp. 60
Mat.Rough. 0.01
Min.V 0
Max.V 0
Wid. 7
Hei. 9.8
SP Loss 0.007
SP Loss Subtotal 0.414

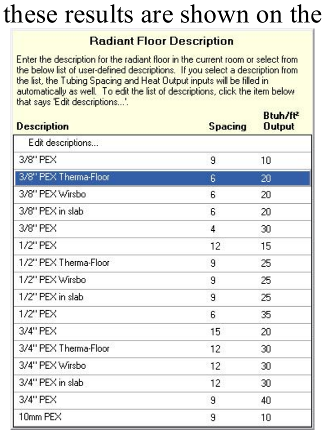

Manual D Duct Sizer - Path 2 of 2
Toggle Rooms/Details
D&F SPL 0.114
TEL 149
Fr. Rate 0.076
Status: OK
Path No. 2
Path Name: Partial Route To Bedroom
Ups. Path 1
Ups. Item 4
System 1
ESP 0
Ups. Loss 0.382
Total Path SP Loss: 0.414
Item 1
Type Duct
Flow 349
Description ST-400
Details >>
Zone 1
1-Living Room
2-Kitchen
3-Bedroom
Regs (if 1 room): 1
Return
Diam. 9.5
Vel. 653
L/100 0.084
Wid. 7
Hei. 11
SP Loss 0.009
SP Loss Subtotal 0.392
Item 2
Type Fitting
Fit.ID 9-A1
Duct Ref. Item Below
Quantity 1
Eq.Length 21.82
Description Fitting 9-A1
SP Loss 0.016
SP Loss Subtotal 0.408
Item 3
Type Duct
Flow 198
Description SR-200
Details >>
Zone 1
1-Living Room
2-Kitchen
3-Bedroom
Regs (if 1 room): 1
Return
Diam. 9
Vel. 447
L/100 0.072
Wid. 7
Hei. 9.8
SP Loss 0.007
SP Loss Subtotal 0.414



Radiant Floor Properties

This dialog (shown with its dropdown help window, below) lets you document the type of floor to be used as well as enter the tubing spacing and heat per area. Rhvac calculates the required amount of tubing to meet the load, the amount needed to fill the room, the total floor heat output, and the amount of supplemental heat required to meet the design load. All of these results are shown on the radiant report.





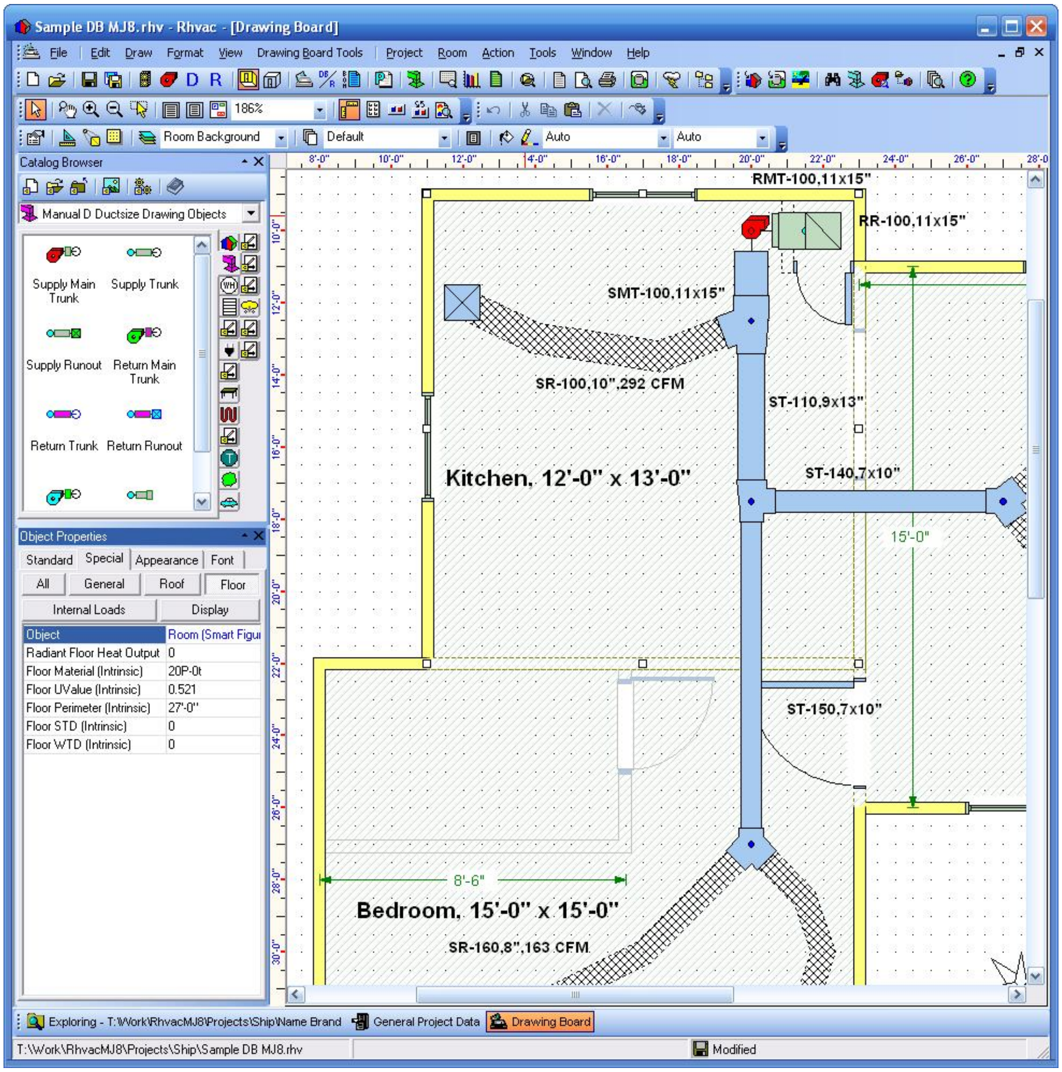
Radiant Floor Description

Enter the description for the radiant floor in the current room or select from the below list of user-defined descriptions. If you select a description from the list, the Tubing Spacing and Heat Output inputs will be filled in automatically as well. To edit the list of descriptions, click the item below that says 'Edit descriptions...'.

Description	Spacing	Btuh/ft² Output
Edit descriptions...		
3/8" PEX	9	10
3/8" PEX Therma-Floor	6	20
3/8" PEX Wirsbo	6	20
3/8" PEX in slab	6	20
3/8" PEX	4	30
1/2" PEX	12	15
1/2" PEX Therma-Floor	9	25
1/2" PEX Wirsbo	9	25
1/2" PEX in slab	9	25
1/2" PEX	6	35
3/4" PEX	15	20
3/4" PEX Therma-Floor	12	30
3/4" PEX Wirsbo	12	30
3/4" PEX in slab	12	30
3/4" PEX	9	40
10mm PEX	9	10

Drawing Board Window

Rhvac includes a Drawing Board window, which operates at the demo level until you purchase a separate license for Drawing Board. The Drawing Board window enables you to enter your room data by simply drawing the floor plan on the screen. Below is a screenshot showing a floor plan created from within Rhvac.



Manual J

When sizing a heating and cooling system for a home, rule of thumb measurements can yield an improperly sized system, but the Manual J method can provide an easy to use quick method of sizing HVAC equipment. Manual J-compliant load calculation software analysis is now required by the City of Austin Building Code for each new residential buildings.

- Calculates ACCA certified Manual J 7th and 8th edition load calculations, including addenda A,B,C and D.
- Worksheets are easy to learn and easy to use!
  This program is quick to use as the worksheets instantly recalculate onscreen with any changes.
- All Manual J tables are included, including mobile homes with improved sizing loads for:
  - Single-family detached homes
  - Small multi-unit structures, condominiums, and townhouses
  - Manufactured homes
- Loads can be broken down by whole house or room-by-room with BTUs and CFMs and viewed as pie charts.
- Multi-zone capability with single central VAV or multi-equipment, including the calculation of peak loads.
- Simple, detailed, and blower door infiltration calculations.
- Handles hydronics including high and low density baseboards.

- Fast links to ResCheck, Rem/Rate for easy code compliance.

A sample set of output data is enclosed:

Winter Design Conditions

Outside db	63	°F
Inside db	68	°F
Design TD	5	°F

Summer Design Conditions

Outside db	88	°F
Inside db	75	°F
Design TD	13	°F
Daily range	L	
Relative humidity	50	%
Moisture difference	33	gr/lb

Heating Summary

Structure	1691	Btuh
Ducts	1191	Btuh
Central vent (26 cfm)	144	Btuh
Humidification	0	Btuh
Piping	152	Btuh
Equipment load	3178	Btuh

Infiltration

Method		Simplified
Construction quality		Average
Fireplaces		0
	Heating	**Cooling**
Area (ft²)	1750	1750
Volume (ft³)	10500	10500
Air changes/hour	0.38	0.20
Equiv. AVF (cfm)	67	35

Sensible Cooling Equipment Load Sizing

Structure	8767	Btuh
Ducts	3263	Btuh
Central vent (26 cfm)	384	Btuh
Blower	0	Btuh
Use manufacturer's data	n	
Rate/swing multiplier	0.93	
Equipment sensible load	11583	Btuh

Latent Cooling Equipment Load Sizing

Structure	773	Btuh
Ducts	521	Btuh
Central vent (26 cfm)	580	Btuh
Equipment latent load	1874	Btuh
Equipment total load	13457	Btuh
Req. total capacity at 0.70 SHR	1.4	ton

Heating Equipment Summary

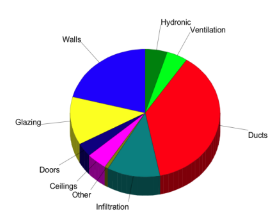
Make		
Trade		
Model		
Efficiency	80 AFUE	
Heating input	0	Btuh
Heating output	0	Btuh
Temperature rise	0	°F
Actual air flow	505	cfm
Air flow factor	0.175	cfm/Btuh
Static pressure	0.50	in H2O
Space thermostat		

Cooling Equipment Summary

Make		
Trade		
Cond		
Coil		
Efficiency	0 EER	
Sensible cooling	0	Btuh
Latent cooling	0	Btuh
Total cooling	0	Btuh
Actual air flow	505	cfm
Air flow factor	0.042	cfm/Btuh
Static pressure	0.50	in H2O
Load sensible heat ratio	0.87	

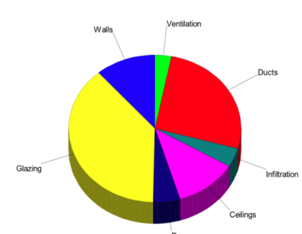
Heating

Component	Btuh/ft²	Btuh	% of load
Walls	0.4	664	20.9
Glazing	2.8	388	12.2
Doors	1.9	109	3.4
Ceilings	0.2	140	4.4
Floors	0.0	24	0.8
Infiltration	0.3	366	11.5
Ducts		1191	37.5
Piping		152	4.8
Humidification		0	0.0
Ventilation		144	4.5
Adjustments		0	
Total		**3178**	**100.0**



Cooling

Component	Btuh/ft²	Btuh	% of load
Walls	0.8	1409	11.3
Glazing	35.0	4758	38.3
Doors	11.2	627	5.0
Ceilings	1.7	1462	11.8
Floors	0.0	0	0.0
Infiltration	0.4	512	4.1
Ducts		3263	26.3
Ventilation		384	3.1
Internal gains		0	0.0
Blower		0	0.0
Adjustments		0	
Total		**12414**	**100.0**



Overall U-value = 0.065 Btuh/ft²-°F

Design Information

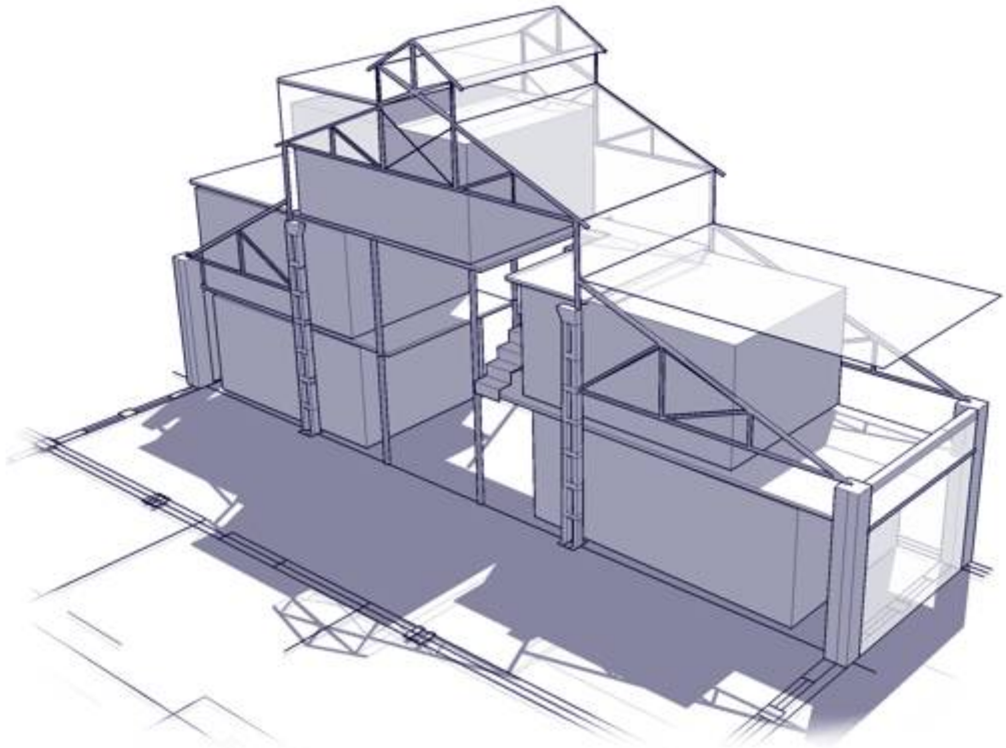
	Htg	Clg	Infiltration	
Outside db (°F)	63	88	Method	Simplified
Inside db (°F)	68	75	Construction quality	Average
Design TD (°F)	5	13	Fireplaces	0
Daily range	-	L		
Inside humidity (%)	-	50		
Moisture difference (gr/lb)	-	33		

HEATING EQUIPMENT			COOLING EQUIPMENT		
Make			Make		
Trade			Trade		
Model			Cond		
			Coil		
Efficiency	80 AFUE		Efficiency	0 EER	
Heating input	0	Btuh	Sensible cooling	0	Btuh
Heating output	0	Btuh	Latent cooling	0	Btuh
Temperature rise	0	°F	Total cooling	0	Btuh
Actual air flow	505	cfm	Actual air flow	505	cfm
Air flow factor	0.175	cfm/Btuh	Air flow factor	0.042	cfm/Btuh
Static pressure	0.50	in H2O	Static pressure	0.50	in H2O
Space thermostat			Load sensible heat ratio	0.87	

ROOM NAME	Area (ft²)	Htg load (Btuh)	Clg load (Btuh)	Htg AVF (cfm)	Clg AVF (cfm)
Living room	150	297	2263	52	95
Dining	140	261	892	46	37
Kitchen	165	345	2086	60	88
Bedroom 1	180	376	1307	66	55
Hall	130	121	423	21	18
Master	240	310	854	54	36
Laundry	77	163	365	29	15
Bedroom 2	168	251	646	44	27
Master Bath	60	142	306	25	13
Office	100	106	323	19	14
Room28	230	212	698	37	29
Mudroom	110	298	1867	52	78
Entire House	1750	2882	12031	505	505
Other equip loads		296	384		
Equip. @ 0.93 RSM			11583		
Latent cooling			1874		
TOTALS	1750	3178	13457	505	505

Google SketchUp Solar Shading Analysis

Various methods have been described for determining shading design for a proposed building in Arc. 334L. These methods involve, performing calculations, using sun path diagrams, or using other tools such as the UTSOA Helidon. The results of these methods do not always give the architecture student the direct visual evidence they desire. SketchUp is a simple, and highly visual way of determining actual shading on a building. By using SketchUp for virtual shade analysis that shows where and how effective shading designs are on the building the student sees visually what any potential shading concerns very quickly. Once the problems become evident to the student they can use SketchUp to refine to redesign and provide another more improved virtual shade analysis.



Google SketchUp is software that you can use to create, share and present 3D models quickly. Most of the third year architecture students already know how to use this software and those that do not can learn how to use the software in a weekend. The software is also useful to build models for Google Earth, or teach solar shading geometry. From simple to complex, conceptual to realistic, Google SketchUp enables you to build and modify 3D models quickly and easily. Google Earth combines the power of Google Search with satellite imagery, maps, terrain and 3D buildings to add the world's geographic information to a solar shading site design analysis. Beyond mapping software, Google Earth is a powerful tool for viewing, creating and sharing interactive and highly visual location-specific information.

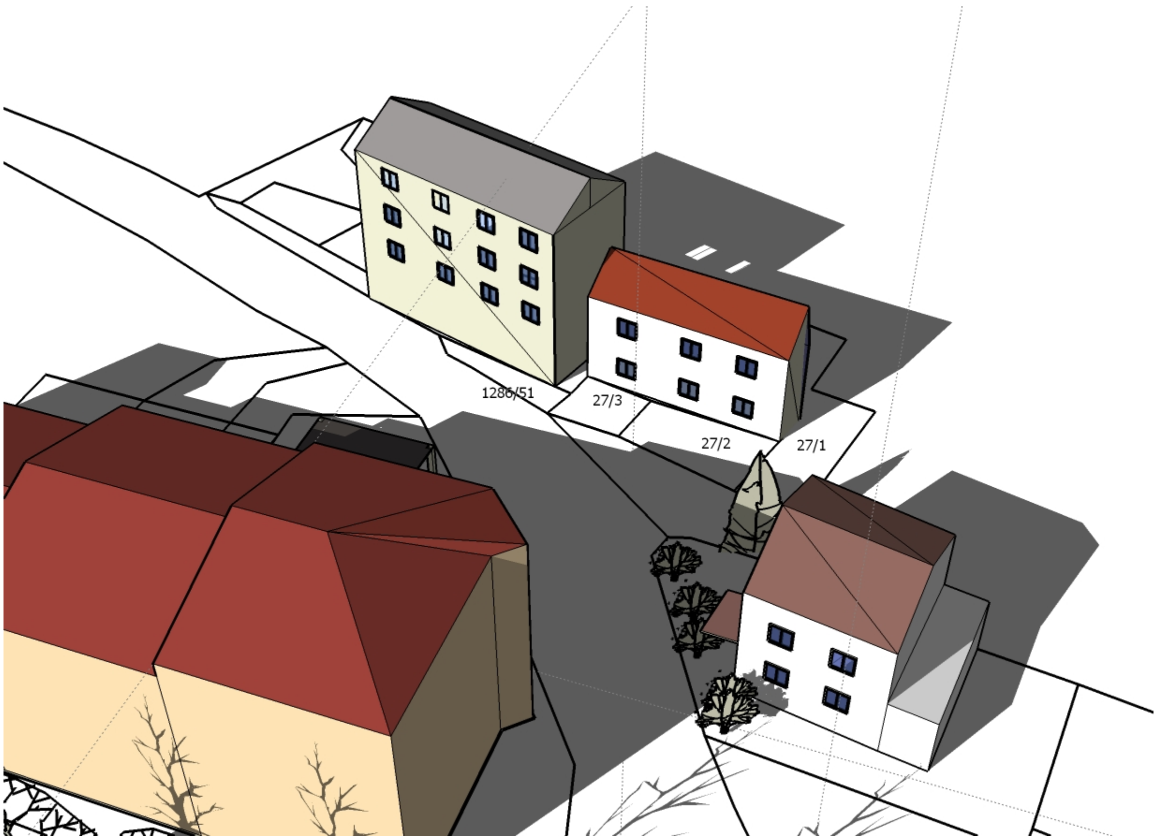
1. Download Google SketchUp, a free, easy-to-use 3-D modeling program. Even if the student has never used a 3-D modeling program, they can learn in a very short time, to create my model. Also download Google Earth, a free program that lets you explore the world through maps and satellite photos. (Find both at www.google.com/options.)

2. In SketchUp, model the site where the building is should be located, including surrounding structures and obstacles. The model can be as simple as a small section of roof or, a rather elaborate model that I will also be used for their design studio purposes.

3. Launch Google Earth and navigate to the site of the solar installation. Switch back to SketchUp and, under the Tool menu, select "Get Current View." SketchUp imports a snapshot of the Google Earth window and sets the latitude and longitude of the 3-D model to the correct values, so the sun's position and path will be correct.

4. SketchUp allows you to simulate sunshine on the site at any time of day with their Shadows menu. Moving the Date and Time sliders in the SketchUp window can allow the student to do shadow studies.

With the use of the SketchUp method when laying out groups of buildings, it's excellent for making sure that specific building features or landscape features do or do not shade adjacent windows during specific times of days.

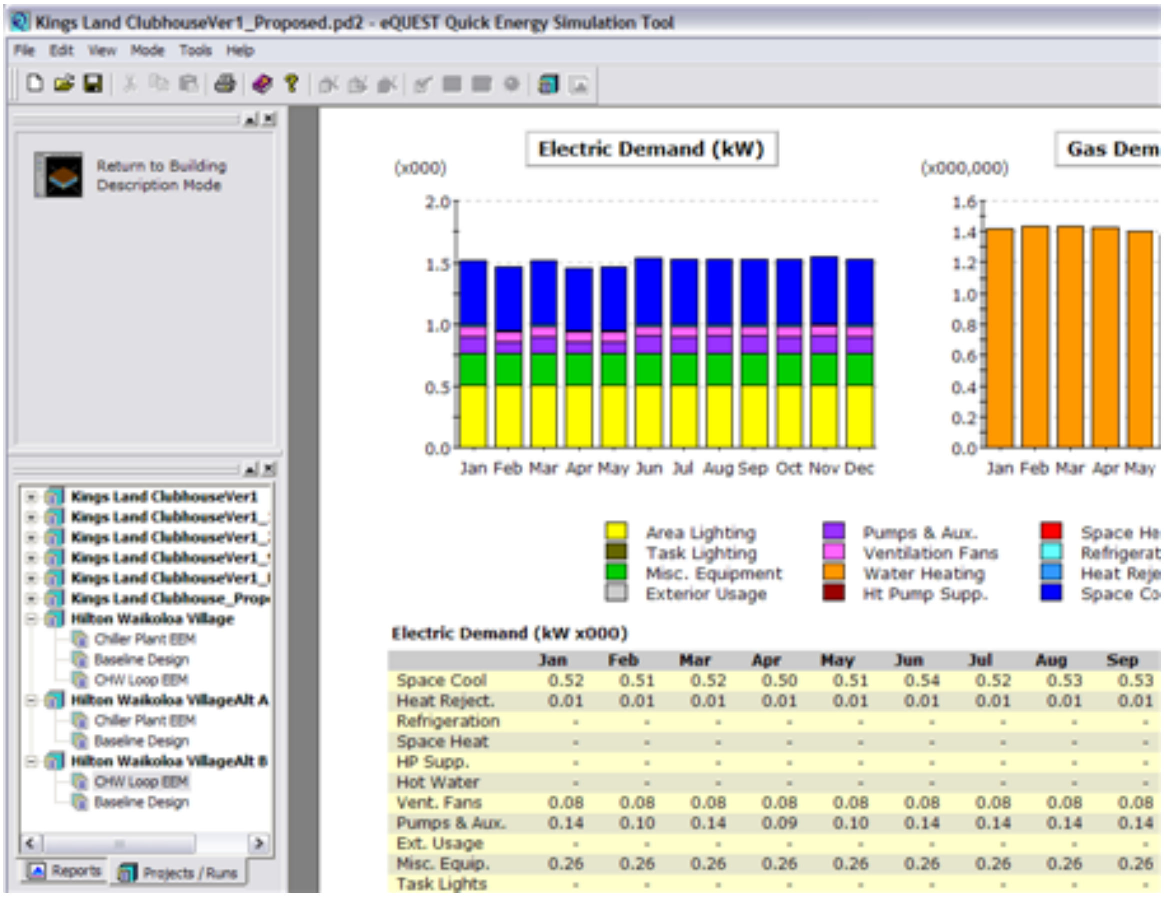


The method is completely free apart from the time needed to create a model. Note that fairly precise measurements of the structure are needed for accurate modeling.

The SketchUp method does not give quantitative information, but it gives a quick visualization of the actual shadows created by landscaping and other features at various times of the day and year. From that, a good estimate of your shading issues can be obtained.

eQuest

eQUEST® is a sophisticated, yet easy to use, freeware building energy use analysis tool that provides professional-level results with a relative short learning curve. eQUEST was designed to allow you to perform detailed comparative analysis of building designs and technologies by applying sophisticated building energy use simulation techniques but without requiring extensive experience in the "art" of building performance modeling. This is accomplished by combining schematic and design development building creation wizards, an energy efficiency measure (EEM) wizard and a graphical results display module with a complete up-to-date DOE-2 (version 2.2) building energy use simulation program.



This tool was used to conduct a whole building energy use simulation of student's design project (after several optimizations using ECOTECT). This was needed because ECOTECT simulates only heating and cooling loads and does not simulate whole building energy use. Results from eQUEST were used as the basis for sizing a HVAC system and subsequently could be useful in calculating the projected carbon footprint of the project. Students were limited to using eQUEST's design development wizard which reduced the number of needed inputs, thus making it possible for students to conduct a relatively quick and reasonably accurate simulation

eQuest

This program combining a building creation wizard, an energy efficiency measure (EEM) wizard and a graphical results display module with an enhanced DOE-2-derived building energy use simulation program.

eQUEST® features a building creation "wizard" that walks the architecture student through the process of creating an effective building energy model. This involves following a series of steps that help describe the features of their design that would impact energy use, such as:

- architectural design, HVAC equipment, building type and size
- floor plan layout, construction materials, area usage and occupancy

). lighting system

The eQUEST® building creation wizard first requests the most general information about the architecture student's building design, and then delves into progressively deeper detail. In all, the building description process comprises 23 data-entry steps – each represented by a "wizard" screen.

At each step of describing the building design, the wizard provides easy-to-understand choices of component and system options. It also offers advice in the form of "intelligent defaults" for each choice. (These defaults are based on more information gathered early in the description process). In addition, eQUEST® automatically skips steps that do not apply to a specific student design.

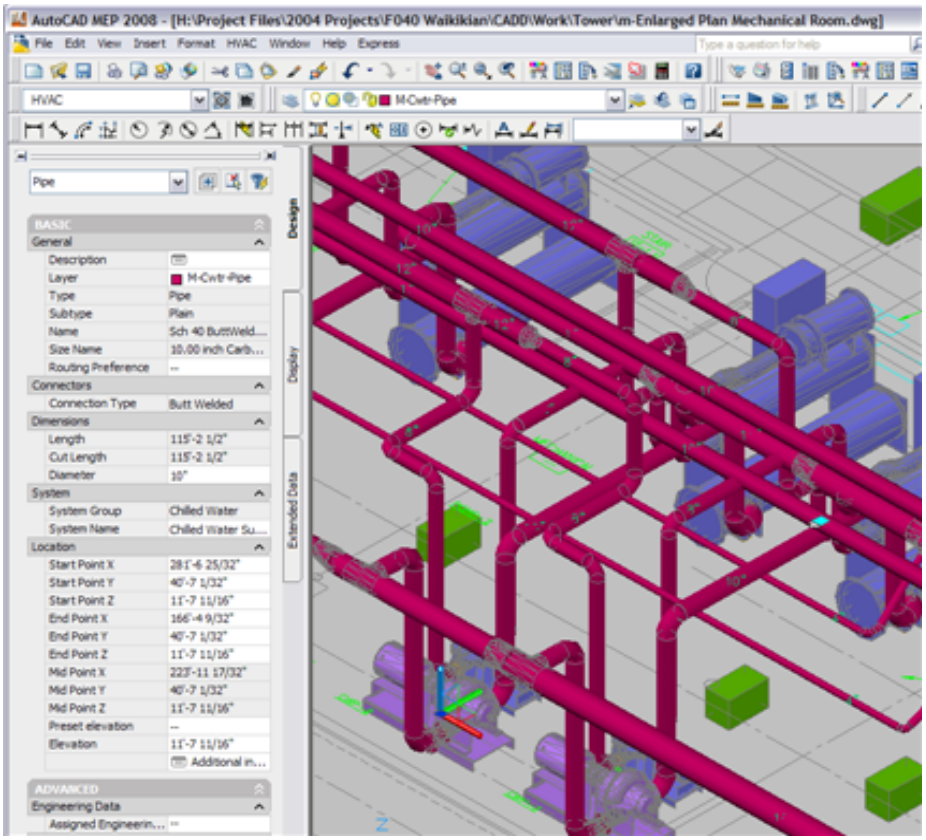
Although the building description process can get quite detailed, it isn't necessary to complete every single step in the wizard. If you choose, you can "bail out" of the description process once you are satisfied with the level of detail. At that point, the wizard fills in any missing information using the eQUEST®'s "intelligent default" process.

After compiling a building description, eQUEST® produces a detailed simulation of the building building, as well as an estimate of how much energy it would use. Although these results are generated quickly, they are quite accurate because this software utilizes the full capabilities of DOE-2 (the latest version of a well-respected and popular building energy simulation program developed over the last 20 years by the U.S. DOE).

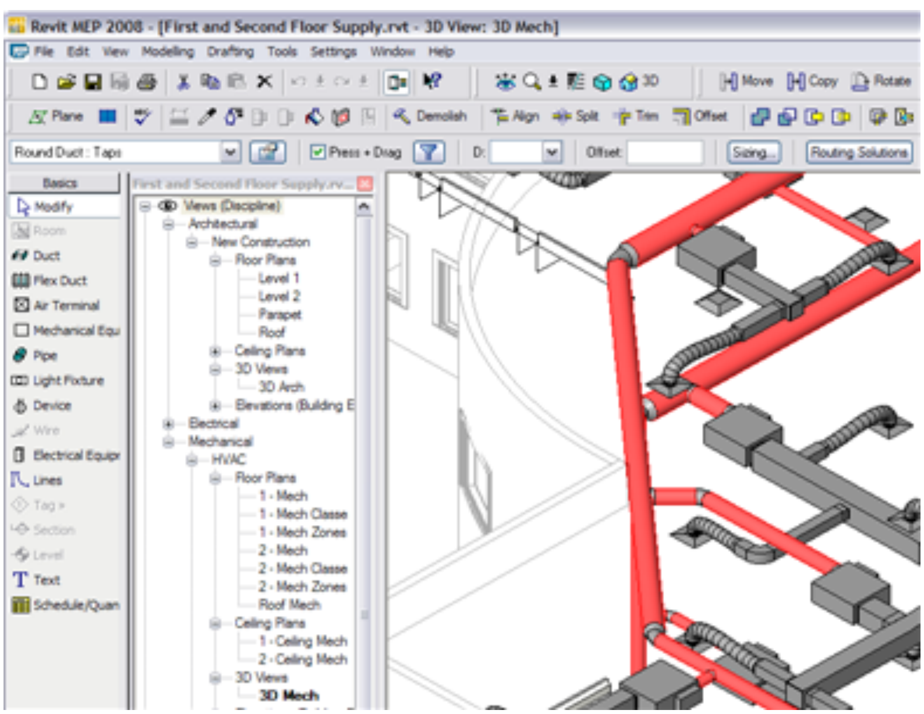
Within eQUEST, DOE-2 performs an hourly simulation of your building design for a one-year period. It calculates heating or cooling loads for each hour of the year, based on the factors such as: walls, windows, people, equipment loads and ventilation. DOE-2 also simulates the performance of: fans, pumps, chillers, boilers and other energy-consuming devices. During the simulation, DOE-2 also tabulates your building's projected energy use for various end uses such as: lighting, plug loads (computers, appliances, copiers, etc.), heating, cooling, ventilation, and pumping.

eQUEST® offers several graphical formats for viewing simulation results. For instance, one can display graphs of estimated overall building energy on an annual or monthly basis. In addition, eQUEST® allows one to perform multiple simulations and view the alternative results in side-by-side graphics. It offers: Energy cost estimating, daylighting and lighting system control and automatic implementation of common energy efficiency measures (by selecting preferred measures from a list).

Version 2.0 of eQUEST® provides even more comprehensive analysis capability. It allows the advanced user to input additional building details to analyze complex buildings. A three-dimensional view of the building geometry is available in this version, as well as HVAC system diagrams.



eQuest Graphics



Rainwater Calculator

Use this calculator to *estimate* how much rain your roof might collect in a year and potentially how much water storage you might need.

Choose the nearest Texas city: --Select--

Choose the type of roof: --Select--

Enter the roof footprint in square feet:

or

Choose a roof size:
- Small
- Medium
- Large

- Store water for landscaping use only?
- Store water for in house use only?
- Store water for both house and landscape?

Calculate   Reset

Note: The numbers derived from this calculator are high-level estimates only and are meant only to give you an idea of your catchment potential. The calculated storage amount needed assumes that you have no back-up water supply and includes a 75 day cushion for dry periods.

Rainwater Calculator

Use this calculator to *estimate* how much rain your roof might collect in a year and potentially how much water storage you might need.

Choose the nearest Texas city: Austin

Choose the type of roof: Metal

Enter the roof footprint in square feet: 2000

or

Choose a roof size:
- Small
- Medium
- Large

- Store water for landscaping use only?
- Store water for in house use only?
- Store water for both house and landscape?

Enter your average monthly landscape water use: 2000

Landscape water use, by default, covers May - October. If you water during other months, please select those months below.

- January
- February
- March
- April
- November
- December

Enter your average monthly household water use: 1000

Calculate   Reset

Texas Rainfall Catchment ℠

Rainwater Harvesting Systems Design and Installation Services

Capture, store and use the best water you can get ®

Rainwater Calculator Results

Inputs	
City	Austin
Roof Type	Metal
Roof Footprint	2,000
Per Month Water Use For	
Landscaping	2,000
Months Landscape Watered	May - October
In House	1,000

Results

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Captured Rain	1,503	2,723	2,048	2,604	4,356	3,421	1,361	1,503	3,527	3,338	2,225	1,681
Water Used	1,000	1,000	1,000	1,000	3,000	3,000	3,000	3,000	3,000	3,000	1,000	1,000
Excess / Shortfall	503	1,723	1,048	1,604	1,356	421	1,639	1,497	527	338	1,225	681

Rainwater harvesting

Rainwater harvesting systems are often designed using some statistical indicator of the rainfall for a given place, like the average rainfall. When the rainfall is meager and shows large fluctuations then a design based on any single statistical indicator can be misleading. As an alternative, graduate TA Steven Matten adopted a new software program http://www.catchtexasrain.com/RainwaterCalculator.html. that takes into account the fluctuations in the rainfall, giving each fluctuation its right importance for determining the size of the rainwater harvesting system. The result of the simulation allows you to design a rainwater harvesting system that will meet demands reliably, that is, it allows you to find the minimum catchment area and the smallest possible storage tank that will meet your demand with probability of up to 95% in spite of the fluctuations in the rainfall. Or you can use this software to find out what fraction of your total demand can be met reliably. Rainwater harvesting is the capture, diversion, and storage of rainwater for a number of different purposes including landscape irrigation, drinking and domestic use, aquifer recharge, and storm water abatement. Regardless of the complexity of the system, the domestic rainwater harvesting system Comprise six basic components:

1. Catchment surface: the collection surface from which rainfall runs off
2. Gutters and downspouts: channel water from the roof to the tank
3. Leaf screens, first-flush diverters, and roof washers: components, which remove debris and dust from the captured rainwater before it goes to the tank
4. One or more storage tanks, also called cisterns
5. Delivery system: gravity-fed or pumped to the end use
6. Treatment/purification: for potable systems, filters and other methods to make the water safe to drink

The methods of determining system sizing are shown below. In the first example, monthly average rainfall data are used, and in the second example, monthly median rainfall data are used for calculations. Monthly rainfall data for several locations in Texas are provided in Appendix B. Keep in mind that the basic monthly water balance calculation is Water available (gallons) = Initial volume in storage (gallons) + gallons captured – gallons used. In an especially wet month, gallons in storage + gallons captured may exceed storage capacity; storage capacity could become a limiting factor, or a slightly larger cistern may be considered.

Assumptions

• Demand of 3,000 gallons/month
• Collection efficiency of 85 percent
• 0.62 gallons per square foot of roof area per inch of rain
• 10,000-gallon storage capacity
• 1,000 gallons in storage on January 1 to start out.

(The water may have been collected between the time of system completion and new home occupancy) Irrigation volume is estimated based upon a small xeriscape landscape, and limited supplemental irrigation, since this example is used for potable supply.

First calculate the number of gallons collected in January. Using the average value of 1.91 inches of rain for January in Austin, the number of gallons of rainwater that can be expected to be stored in January from a 2,500-square-foot roof assuming 85% collection efficiency is determined from the equation: Rainfall (inches) x roof area x 0.62 gal/sq ft /in. rain x collection efficiency. In this example: 1.97 in. rainfall x 2,500sq. ft. catchment x 0.62-gallons/in. rain/sq. ft. x 0.85 collection efficiency = 2,595 gallons. To calculate gallons in storage at the end of each month, add the volume of water already in storage (1,000 gallons in this example) to the gallons collected and subtract the monthly demand. 1,000 + 2,595 – 3,000 = 595 gallons available in storage at the end of January. This calculation is repeated for each month.

Introduction

Architectural energy analysis software helps designers evaluate the solar, thermal, acoustic, resource usage and other properties of their building designs. Orientation, configuration, glazing, materials, local climactic conditions and more are among the many variables analyzed by leading programs. This analysis can predict the annual energy consumed by a structure, costs associated with energy consumption or pollution avoidance. In the past, few buildings benefited from energy analysis. Today, digital models created early on in the schematic design phase can be imported into energy analysis software allowing designers to evaluate their building's performance before the design is finalized.

Other software programs help to size mechanical systems, including the HVAC system and ducts, once the heating and cooling building loads have been calculated. Almost all buildings of any complexity have a sizing analysis of some kind run by an architect, engineer, or mechanical contractor.

At the University of Texas School of Architecture, students in Michael Garrison's undergraduate Environmental Controls I & II classes have until now used longhand calculations to compute heating and cooling loads, size HVAC systems and size necessary ducting. Although effective, these procedures are laborious and as a result do not provide the immediate feedback we are accustomed to in the digital age. Since many students already build digital models of their designs, much of the information necessary to obtain valuable energy performance feedback is already there.

Project Goals

This project seeks to introduce students to cutting-edge energy analysis and sizing software and demonstrate how its use can inform design early on. A key component was how to integrate and use software but to do so in a manner which did distract students from the architectural principles at hand. Therefore, a balance was sought between software performance and ease of use.

Our primary interest is to integrate software capable of four tasks:

- Solar Analysis
    - Effectiveness of shading devices
- Thermal Analysis
    - Heating Loads
    - Cooling Loads

- Equipment Sizing
    - HVAC system sizing
    - Duct sizing
- Rainwater Harvest Calculator

Process
This project will occur in three phases: first, a determination will be made as to which of the many energy analysis programs is the most suitable for use in this class. Second, the chosen software programs will be learned by Michael and myself. Third, the existing homework exercises will be reconfigured to incorporate the chosen programs.

Since many software programs exist to analyze thermal and solar building physics, certain criteria had to be developed to help determine which potential program was most appropriate. These were,

- Functionality
- Quality of interface
- Integration with other modeling programs
- Update frequency

In determining which programs were to be most suitable, the following were considered:

- HEED
- Energy Scheming
- Building Design Advisor
- Shadows & Reflections
- Energy10
- Manual J
- RHVAC
- Ecotect
- Blast
- EnergyPlus
- eQuest
- SketchUp
- Sun Tools
- Autodesk Mechanical, Electrical & Plumbing
- DOE3

Selection
Since different programs specialize in particular types of building analysis, several were chosen to achieve our ends. Doing so presents benefits and challenges since using several software programs both

introduces students to a larger range of software but also requires them learn more software. However, each was chosen largely due to its relative simplicity to perform the desired tasks without becoming overly complex.

Shading Analysis

SketchUp was selected for the window shading analysis because of its intuitive interface and easy-to-control shadows. Students will be provided with a digital model of a building and they will be asked to design window shades for it. Specifically, their challenge is to provide shade for the windows on certain days of the year. At the same time, students will tally their window shade area and compete amongst themselves for who can achieve the desired shading with the least area. SketchUp provides the perfect interface for designing and testing these shading devices.

Thermal Analysis

eQuest was selected as our thermal analysis software program since it will allow students to easily input critical data for their studio building designs without requiring a completed 3D model. Once the information is inputted, eQuest generates large quantities of useable data using it's robust DOE simulation engine. This data will provide accurate ball-park figures of heating and cooling loads that will reveal to the students the thermal implications of their design moves.

Duct Sizing

A simple spreadsheet will be used to calculate air flow rates required to heat/cool a space based on the thermal results generated in the Thermal Analysis. Once the students know the required air flow rates, a chart in Michael Garrison's ECII text will allow students to determine the necessary size of their ducts.

Rainwater Analysis

A web-based calculator inputs the roof area and building location and generates an annual rainwater estimate. It even estimates the landscaping area potentially watered by this quantity.

Implementation

A weekly lab class will introduce the software to the students. Step by step instructions will allow students to learn the software at their own pace. The three teaching assistants will be available outside of class to help students solve problems along the way.

ECII: Homework 1 - Solar Shading Mask Design

Objective
Design and test the effectiveness of your solar shading masks for the given office pavilion and demonstrate that they achieve the minimum 50% Window Shading goal.

You may do this digitally, using SketchUp and following this guide, or physically using a model and the Heliodon. For those choosing the physical model, a demonstration of the Heliodon will be scheduled.

Procedure

- Download and install Google SketchUp (http://sketchup.google.com/)
- Design and model your office pavilion and shading masks.
- To test your shading masks, create Elevation view *Scenes* in Parallel Projections of your various facades at the specified times of day/year.
    - How to do this:
        - View your model in Parallel Projections:
            - Go to *View/Parallel Projections*
        - Specify the times of day/year:
            - Go to *Window/Shadows* and enter in the given Time/Day. Also make sure *Display Shadows* is checked.
        - View Elevation:
            - Go to *Camera/Standard Views* and select one of the elevation views
        - Make Windows Opaque: Transparent windows don't show shadows hitting them, so it's better if you make your windows opaque
            - Select the *Paint Bucket* tool in the *Tool Palette*, select an opaque window color and click on your windows to apply it
        - Make Scene: Once you're satisfied with your view, make a scene of it
            - Go to *Window/Scenes*
            - Click on the circled plus symbol
            - Enter a name of the scene (eg *West Elevation 6/21 @12pm*)
            - Click on the circular arrows button (looks like a recycle symbol) to update your new scene to the view you've created
        - Repeat this process for each elevation
            - In the end you'll end up with 4 or so elevation Scenes that you can jump between and export images from
- Modify your shading masks until your scenes demonstrate that they meet the required shading percentages
- When satisfied with your design, Export a jpg image from each scene showing the effectiveness of your shading devices

Deliverables (Due February 1, 2010, 10 pts)

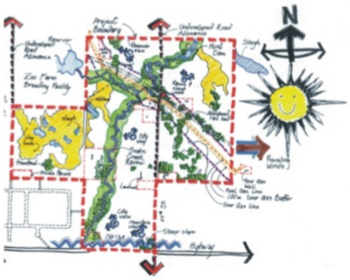
- Building Plan at 1/4"=1'
- Building Section at 1/4"=1'
- Building Model at 1/4"=1' (only for those making a physical model)
- Elevation Views/photographs of each façade (demonstrating shading mask effectiveness) at noon on January 21, June 8, September 1
- A 200 word statement describing the building and its environmental controls systems

Given that the Interiors students did not find the exercise on solar shading and site analysis helpful for their design work in interior design an alternative homework assignment was given to the interior design students.

EC II - Homework 2: Site Analysis

Due: Feb 22, 2010

"Any existing, functioning site has a structure and an identity. If it did not, it would be uninhabitable." – Kevin Lynch



Site analysis seeks building forms that interact symbiotically with the site. The climate, for instance, affects buildings' shapes and building shapes alter the microclimate. How can this relationship be exploited?

The principals of design with climate conceive of the building skin as the filter between inside and outside, tempering temperature, humidity, light levels, noise etc. The more climatic tempering the filter is required to perform, the less mechanical equipment is needed. After all, why expend nonrenewable energy resources on a job that could be achieved with sensitive, smart design?

The topics covered in this exercise include;

1. Design with Climate
2. Topography and Microclimate
3. Wind flow and Vegetation
4. Solar Gain and Shading

The analysis serves to identify the strengths and weaknesses of the site by focusing on four interrelated topics: **Topography, Orientation, Presence and Orientation**.

Topography and **Orientation** identify how each portion of the site might best be used with respect to views, accessibility, sun and slope. Regarding these, consider how your site:

- Plays a role in defining the limits of the city block
- Addresses the flow of vehicular and pedestrian traffic
- Defines the limits of private and public space

Presence and **Context** look at the surroundings and consider how the building might best contribute to its environment. They also focus on the clues derived from these surroundings and the way in which they inform the design. Regarding these, consider how to:

- Locate your building in the area of least winter solar shadow (look at annual shadows cast by surrounding buildings)
- Shade occupants and activities from harsh solar conditions
- Organize the massing so that the building receives adequate solar gain for passive heating and PV power

You are asked to prepare a site analysis and building massing for your sound building project. If your design program is not totally developed you should assume a generic 15,000 square foot car dealership to be located on the site.

As evidence of your completion of these investigations, the following items should be turned in, typed in a format not to exceed 11" x 17"

1. A statement (1 page) of your microclimatic goals for the building massing site design
2. An analysis of existing wind flow and vegetation on the site
3. An analysis of the existing topography and microclimate(s) on the site
4. An analysis of the existing solar shading on the site for winter, summer and spring
5. An analysis of the microclimatic implications of your proposed building massing site design scheme
6. A statement (1 page) of your conclusions

HW2 for Interior Design Students – Daylighting Design

For this assignment you are asked to choose wall, ceiling and floor materials based on calculated reflectance values and present them in a Kerkythea rendered perspective section drawing of your space.

Note: SketchUp, Kerkythea and this assignment will be covered in lab on February 22, 2010 **so interior design students please be there.** Also, for further reference, please see pages 21-27 in your EC II course packet.

Either collectively or individually, you should model in SketchUp your space, using accurate window sizes and positions. Once modeled, use SketchUp to determine A, the total indoor surface area and W, the net glazing area. Then, gather and/or estimate the remaining terms for the Daylight Factor equation: T=Transmittance of glazing, θ=subtended angle).

$$\text{Daylight Factor} = \frac{\mathrm{T} \cdot \mathrm{W} \cdot \theta}{\mathrm{A}(1-\mathrm{R}^2)}$$

Since your space has glazing on the north and south sides, your Daylight Factor equation will take the form:

$$\text{Daylight Factor} = \%\ \text{North Windows} \cdot \left[\frac{T \cdot W \cdot \theta}{A(1-R^2)}\right]_{North} + \%\ \text{South Windows} \cdot \left[\frac{T \cdot W \cdot \theta}{A(1-R^2)}\right]_{South}$$

Using the charts in the text, select an appropriate Daylight Factor and using the above equation solve for R. Remember, this is the weighted average reflectance of all indoor surfaces. To calculate the reflectance of just the walls, you'll need to choose two reflectance values (for instance the floor and ceiling) and using them with the weighted reflectance equation below calculate the wall's reflectance.

$$\text{Weighted Reflectance} = \frac{R_{walls} \cdot A_{walls} + R_{ceiling} \cdot A_{ceiling} + R_{floor} \cdot A_{floor}}{\text{Total area of all surfaces}}$$

Once you've calculated/chosen reflectance values for your walls, ceiling and floor you need to choose materials that will provide those reflectance values. You may do this either by choosing them from the charts in the text or by measuring the reflectance values yourself using a light meter.

Deliverables

- A written (one page) description of your process, including any choices you made along the way and their significance
- A Kerkythea rendered section perspective showing how daylight enters your space and how it reflects off the various, labeled material surfaces
- A summary of your calculations

Thermal Analysis with eQuest

Objective
Calculate energy consumption and heating & cooling building loads for you studio design projects to use as a comparison to your hand calculations.

This analysis will take into account the following factors:

- Building Location
- Solar Orientation
- Window Size & Placement
- Materials & Construction
- Occupant Heat
- Internal Gains (equipment & lighting)
- And much more!

Introduction
eQuest (QUick Energy Simulation Tool) is the latest manifestation of the DOE's robust building simulation engine.

Data entry occurs via a software wizard and generates a 3D model as you go. The most basic information is entered first, including the building size, location, type, construction etc. From those selections, eQuest displays default values for hundreds of other parameters that the building simulator may either accept or change.

This assignment is about generating ballpark figures of your heating & cooling loads. You are not expected to know all the information eQuest asks for. Except for the specific information listed below, you can leave most of the default values as is. In your written report you will have a chance to comment on the effects of your selections.

Before you begin with eQuest, it's advisable to gather the information it needs. If you have this ready, the data entry and simulation will be very quick.

- Building Type
- Location
- Number of Floors
- Footprint Shape and Dimensions
- Interior Zoning Pattern
- Orientation
- Floor to Floor Heights
- Average Window and Door Dimensions
- Window and wall areas and their ratios for each exterior wall

Procedure

- Download and install eQuest (~45Mb, Windows only)
    a. http://www.doe2.com/eQUEST/
- Run eQuest. On the first screen, select the **Create a New Project via the Wizard** option.
- In the second screen, choose **Schematic Design Wizard**.
- Move through the remaining 41 wizard screens. On another piece of paper write down your selections for the following fields to include in your report.

    a. **Screen 1** – General Information
        i. Building Type
        ii. Location Set
        iii. Building Area
        iv. Number of floors
    b. **Screen 3** – Building Footprint
        i. Footprint Shape – under Custom you can import a DWG if you want
        ii. Zoning Pattern
        iii. Building Orientation
        iv. Footprint Dimensions
        v. Floor Heights
    c. **Screens 6 & 7** – Exterior Doors & Windows– Here you need your door and window information

- Click the **Finish** button when you have completed the last wizard screen. In the new window that opens, click on the **Building Shell** tab, then the **3-D Geometry** tab. Print out a PDF or do a screenshot of your 3D building and include it in your report.
- Click on **Simulate Building Performance** in the left column toolbar. When the simulation is complete, click on **View Summary Results/Reports**
- Print as PDF the **Monthly Energy Consumption by End Use** for analysis
- Now we want to look at eQuest's calculation of the building loads. Go to Tools/View Simulation Output. In the flyout menu, scroll down to *LS-D Building Monthly Loads Summary.* This page shows the heating and cooling building loads for each month. Export out this page for analysis.

Deliverables - in addition to your hand calculations, please provide:

- The 3D image of your building generated by eQuest
- The Monthly Peak Energy Usage chart generated by eQuest
- The LS-D Building Monthly Loads Summary
- A list of the information you entered in screens 1, 3, 6 & 7
- A one page written report discussing your eQuest simulation, the energy consumption, and how its building loads compare to your hand calculations. How accurate is the eQuest simulation? What might account for differences between it and the hand calculations?

HVAC & Duct Sizing

Objective:

1. Calculate the number of tons of required air conditioning cooling
2. Calculate the required air flow rate for heating
3. Calculate the cross-sectional duct size of air handling ducts

Procedure:

1. Tons of Air Conditioning Cooling Required
    a. Find the Total Cooling load value from eQuest's *Detailed Simulation Output File*
    b. Divide that value by 12,000 BTUH to determine the total number of tons of air conditioning required.
    c. Determine how many square feet are cooled by 1 ton of air conditioning

2. Heating Air Flow Rate
    a. Find the Total Sensible Heat Load from eQuest's *Detailed Simulation Output File*
    b. Divide that value by 12,000 BTUH to determine the total number of tons of air conditioning required.
    c. Divide that value by 400 CFM to establish total air flow rate (since air conditioning equipment usually circulates about 400 CFM for each ton of capacity)
    d. Round off to the nearest 25 CFM

3. Cross-sectional Duct Size
    a. Using your CFM air flow rate and the Duct Size Table in the ARC 334L text, determine the required duct size

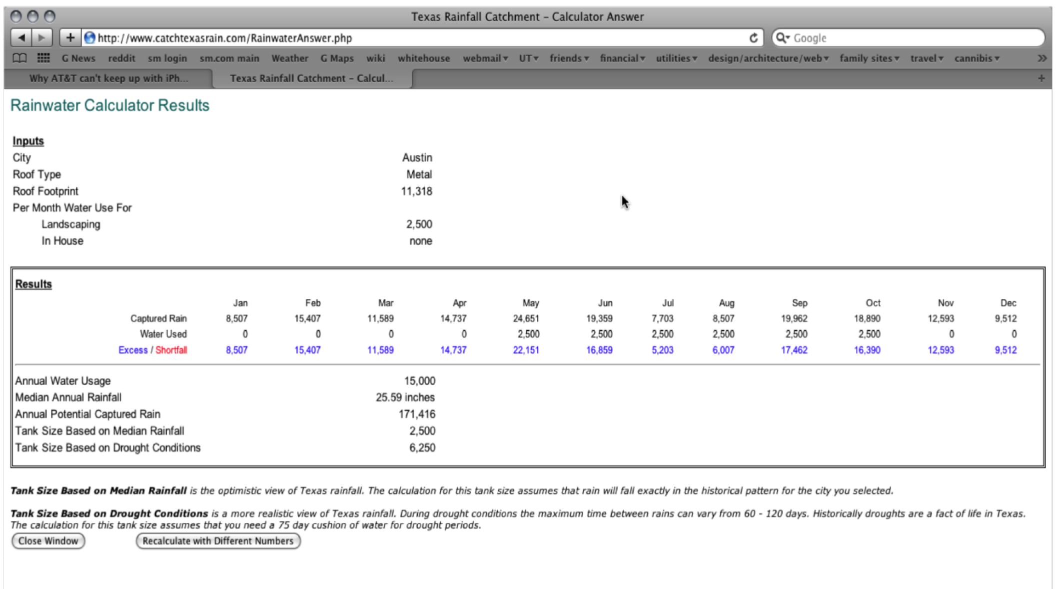
Deliverables
Please submit a one page summary of your calculations, showing clearly your process and results.

Grading
You will be graded on the accuracy, clarity and completeness of your work

Rainwater Analysis

Objective
Calculate the annual volume of rainwater falling on your roof and estimate for how long it will meet your landscape watering needs

Procedure
1. Calculate roof footprint in sqft. This is the horizontal projection of your roof onto the ground, not the actual roof area
2. Using the following web-based calculator, enter the nearest city, select the type of roof and the roof footprint in sqft. Select the option to *Store water for landscaping use only.*
3. Take a screen shot of the results



Rainwater Calculator Results

Inputs

City	Austin
Roof Type	Metal
Roof Footprint	11,318
Per Month Water Use For	
Landscaping	2,500
In House	none

Results

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Captured Rain	8,507	15,407	11,589	14,737	24,651	19,359	7,703	8,507	19,962	18,890	12,593	9,512
Water Used	0	0	0	0	2,500	2,500	2,500	2,500	2,500	2,500	0	0
Excess / Shortfall	8,507	15,407	11,589	14,737	22,151	16,859	5,203	6,007	17,462	16,390	12,593	9,512

Annual Water Usage	15,000
Median Annual Rainfall	25.59 inches
Annual Potential Captured Rain	171,416
Tank Size Based on Median Rainfall	2,500
Tank Size Based on Drought Conditions	6,250

Tank Size Based on Median Rainfall *is the optimistic view of Texas rainfall. The calculation for this tank size assumes that rain will fall exactly in the historical pattern for the city you selected.*

Tank Size Based on Drought Conditions *is a more realistic view of Texas rainfall. During drought conditions the maximum time between rains can vary from 60 - 120 days. Historically droughts are a fact of life in Texas. The calculation for this tank size assumes that you need a 75 day cushion of water for drought periods.*

Close Window   Recalculate with Different Numbers

Deliverables
Please submit a screen shot of your rainwater calculator results, as shown above.

Grading
You will be graded on completeness.

Conclusions

Homework
Each of the four homeworks is a valuable and worthwhile exercise. That said, there exists room for improving the clarity and formatting of the handouts. They should be clear, simple and concise and contain all the relevant information, such as requirements, due date, support information etc.

This semester two of the four homeworks included for the first time software components intended to introduce various computer modeling techniques. Students used SketchUp for solar shading analysis and used eQuest for thermal analysis. Some of the challenges resulted from this new software. At the same time, the use of the software raised some fundamental questions about how the assignments are structured, including:

1. How best to allow students to use software to analyze architecture? Do they model their own building or are they given a digital file of a modeled building?
2. How best to incorporate software but keep the learning curves minimal?
3. How do students obtain/install/troubleshoot software?
   a. Is the software free or pay?
   b. Do they install it on their own machine or only on school machines?
   c. Is it cross platform?
   d. Who helps with installation problems?

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Homework 1 - Solar Shading
Overview
Students were asked to design and model kiosks with solar shading devices intended to achieve a 50% shading goal for three dates and times of the year. They were asked to use SketchUp and to generate elevation images at those times of the year to show the shading effectiveness. Alternatively, they were allowed to build a physical model and use the Heliodon and a camera to investigate the effectiveness of their shading devices.

Deliverables
1. Building Plan at 1/4”=1’
2. Building Section at 1/4”=1’
3. Building Model at 1/4”=1’
4. Elevation Views/photographs of each façade (demonstrating shading mask effectiveness) at noon on January 21, June 8, September 1
5. A 200 word statement describing the building and its environmental controls systems

Issues
1. The dates and times did not cover the whole year, which meant it was hard to clearly see how effective the shades were
2. Students had varying levels of SketchUp ability
3. Wide variety of designs and types of shade structures resulted in a wide variety of work

Recommendations
1. Replace the still images with a sun study animation. These are easy to generate in SketchUp and more clearly show a window shade’s effectiveness for a whole day or year. One animation could be generated for each facade with glazing.
2. Consider provide students with SketchUp model of a generic kiosk (or other building) and have them design just the shade structure. This focuses their effort of just the shading device design and could lead to more standardized output that could be compared to other students’ work.
3. If the software is too cumbersome, consider requiring all students to build physical models and use the Heliodon only. This would require a proper Heliodon demonstration.
4. Consider rescheduling this assignment as the second homework. This would allow Site Analysis to be the first assignment which is perhaps more fitting with the students’ studio work process. Secondly, the students would be able to use this assignment to design a shading structure for their own studio projects rather than for another building.
5. More emphasis on wider glazing issues should be put on this assignment. Mapping important views, program/light level relationships etc are considerations in addition to preventing solar insolation.

Homework 2 - Site Analysis

Overview

Students were asked to analyze the site of their studio projects. No software was explictly required. They were asked to look at design with climate, topography and microclimates, window flow and vegetation & solar gain and shading.

Deliverables

1. A statement (1 page) of your microclimatic goals for the building massing site design
2. An analysis of existing wind flow and vegetation on the site
3. An analysis of the existing topography and microclimate(s) on the site
4. An analysis of the existing solar shading on the site for winter, summer and spring
5. An analysis of the microclimatic implications of your proposed building massing site design scheme
6. A statement (1 page) of your conclusions

Issues

1. Many students showed an inability to conduct proper site analysis and submitted web graphics of wind roses, vegetation types, solar charts etc.
2. The handout may have added more confusion than clarity
3. The Interior Design students require a thoughtfully worked out alternative to this assignment.

Recommendations

1. Review in class examples of good site analysis
2. Rework the handout to be specific and clear
3. Emphasize that *site analysis* isn't downloading and printing web images
4. Can the interior students gather "site" information related to EC? How about toxicity report of existing materials? What can be done to reduce insolation? Does the program align with the environment? How can an interior designer improve the indoor air quality?

Homework 3 - Thermal Analysis

Overview

Students were tasked with using both eQuest and hand calculations to find the peak building loads for the studio design projects. The hand calculations were pretty straight forward and went well, but many students complained that the software didn't allow them to accurately represent their design.

The large challenge in selecting software to allow untrained students to perform thermal analysis is ease of use. The benefit of eQuest is that it is easy since it allows you to thermally simulate a building without having to fully model it. The tradeoff is that there are limitations to the level of detail you can include.

Deliverables

1. Hand calculation of building load
2. The 3D image of your building generated by eQuest
3. The Monthly Peak Energy Usage chart generated by eQuest
4. The LS-D Building Monthly Loads Summary
5. A list of the information you entered in screens 1, 3, 6 & 7
6. A one page written report discussing your two building load calculations

Issues
1. The major complaint was that eQuest wouldn't allow them to accurately represent their building. The hand calculations went well.

Recommendations
This assignment brings us back to one of the central questions of how to structure this course: do we provide digital building files to which the students perform various analysis, or do they model and analyze their own work?

Digital thermal building analysis requires sophisticated software and a detailed digital model and therein lies the challenge. Without turning ECII into a much more software-intensive course, it's hard to train 70 students on software and then get their studio designs modeled and analyzed in just a few weeks.

1. Hand calculations are used exclusively
2. Students receive a digital file of a fully modeled building and they thermally analyze it. Revit and MEP have this functionality built in and the school has contacts at AutoDesk.
3. A software person is brought in to demonstrate high-order computer thermal analysis for the students to observe only.

Here is a sample of students' building loads calculated both from eQuest and the hand calculations.

eQuest - MBTU/Hr	Hand Calcs - MBTU/Hr	SQFT	% Similar (eQuest/Hand Calcs)
71	764	14700	9%
1141	681	17400	168%
290	506	15000	57%
370	1007	5500	37%
462	1170	21000	39%
320	694	13000	46%
318	418	15000	76%
635	863	18000	74%
513	863	22000	59%
1034	613	15000	169%
612	1620	15000	38%
632	418	31100	151%
1348	1292	15000	104%
4675	1414	13000	331%

Homework 4 - Duct Layout
Overview
The final exercise has the students take the building load generated in Homework 3 and use it to layout and size a duct system for their studio design projects.

This assignment went pretty smoothly. Since it was the last some students failed to give it the time it required, which was significant.

Deliverables
1. A color coded plan showing zones, zone loads, return/supply ducts and mechanical room.

2. A one page statement describing their project and duct layout

<u>Issues</u>

1. The handouts were too numerous and convoluted. The deliverables were listed on different documents rather than in one place.

<u>Recommendations</u>

1. Show examples of well done duct layout
2. Simplify exercise handouts and make sure deliverables are listed in one place
3. Put together summary of do's and don'ts for duct sizing